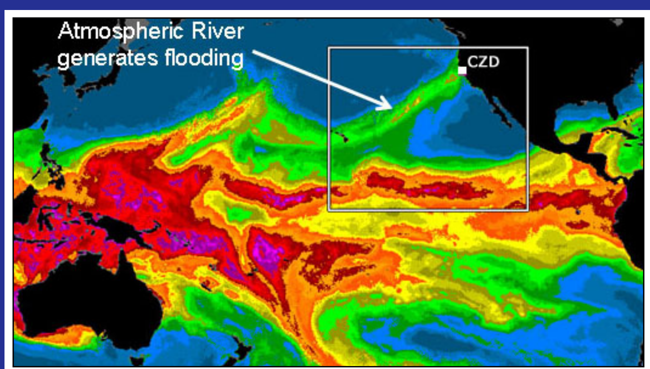
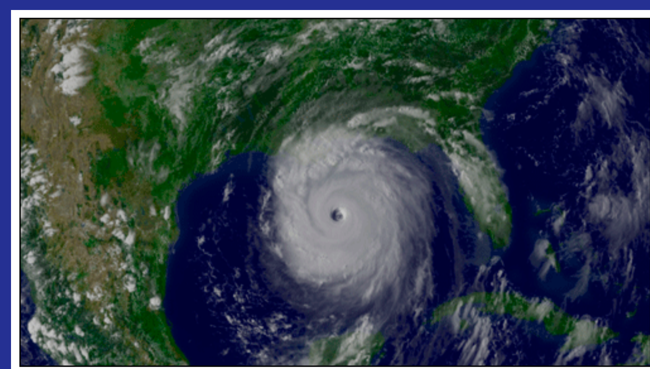
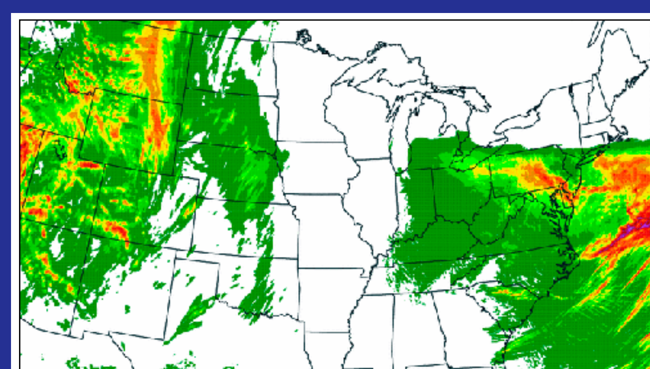
1st NOAA Testbed USWRP Workshop

Abstract Book







April 28–29, 2009

David Skaggs Research Center
325 Broadway
Boulder, CO

NOAA Testbed USWRP Workshop

28-29 April 2009

NOAA Earth System Research Laboratory, Boulder, Colorado

Tuesday, April 28th

7:45 Registration, coffee & light breakfast / Check-in & logistics information

8:45 **OAR & NWS Welcome** – *Sandy MacDonald, Director, ESRL & OAR DAA Labs & Coop Institutes*
Don Berchoff, Director, NWS Office of Science and Technology

9:00 **USWRP Director Welcome** – *Marty Ralph*

9:15 **Overview of Testbeds**

The Developmental Testbed Center: Past, Present & the Future – *Steve Koch (ESRL)*
Societal Impacts Program – *Rebecca Morss (NCAR)*

10:15 Break

An Overview of the Hydrometeorology Testbed – *Tim Schneider (ESRL)*
Overview of the CSTAR Program – *Sam Contorno (NOAA)*
Joint Hurricane Testbed – *Jiann-Gwo Jiing (NWS)*

12:00 Lunch (on-site)

12:45 **Testbed Roundup 1 – Hydrometeorology Testbed & CSTAR**

2:00 Break & light snack

2:15 **Testbed Roundup 1 – Hydrometeorology Testbed & CSTAR *(cont.)***

3:00 **Testbed Roundup 2 – Developmental Testbed Center**

3:45 **Testbed Collaborations** – Joint Efforts between the DTC and the HMT – *Barb Brown (NCAR)*

4:15 **Day 1 Wrap-up –** *Marty Ralph*

4:30 **Adjourn**

6:00 Dinner (Zolo)

ALPS WORKSTATION DEVELOPMENT FOR HMT AND OTHER WORKSTATION TESTBED ACTIVITIES IN GSD

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Abstract

For nearly 30 years the Global Systems Division, and its predecessors FSL and PROFS, have been conducting testbed activities and risk reduction exercises for the National Weather Service and other government agencies. The most notable of these activities led to the successful development and deployment of the Advanced Weather Information and Processing System (AWIPS).

The Advanced Linux Prototype System (ALPS) was developed as an extension to AWIPS in order to test and refine workstation capabilities beyond the baseline AWIPS system. The HMT ALPS has provided high-resolution model data and additional observational data to NWS forecast offices in the HMT study area. Testing over the past three years has shown a steady improvement in usability and utility of the HMT products for operations.

A review of these activities will be presented as well as lessons learned from this and other previous testbed activities.

A WIND PROFILER AND GPS-BASED WATER VAPOR FLUX TOOL FOR PRECIPITATION FORECASTING IN COASTAL MOUNTAINS

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Abstract

The skill of quantitative precipitation forecasts (QPF) is often poor, including for extreme precipitation events enhanced by orography. This paper describes a new prototype operational tool that combines coastal wind profiles recorded by all-weather wind profiling radars with collocated integrated water vapor (IWV) measurements derived from global positioning system (GPS) receivers to estimate the bulk transport of water vapor, a process that contributes significantly to mountain precipitation enhancement. Based on earlier orographic precipitation work in California's coastal mountains, a controlling wind layer is defined that has maximum correlation between the horizontal component of the upslope wind in that layer and the rainfall measured downstream along elevated terrain. The altitude of the maximum correlation (~1 km above sea level) often corresponds to the altitude of the low-level jet that is typically present in the warm sector of approaching midlatitude cyclones and that often bears little resemblance to the wind measured at the surface, thus highlighting the need to obtain upper-air wind measurements for this particular application. The upslope wind in the controlling layer is then combined with the simultaneously measured IWV to calculate hourly, layer-mean, bulk water vapor fluxes. Although IWV is a column-integrated value, water vapor is typically concentrated in the lower troposphere. Hence, to first order, the bulk water vapor flux provides a close estimate of the low-level water vapor transport into the coastal mountains. An analysis of four winters of data demonstrate the close relationship between the magnitude of the bulk water vapor fluxes and mountain precipitation. These results are integrated into a prototype real-time diagnostic tool that has the potential to improve short-term QPF in coastal mountains. The newest generation of this tool also displays realtime model output from the WRF-ARW that is reinitialized and run hourly by using the local analysis and prediction system (LAPS). The model forecasts of local orographic forcing and precipitation are compared with their observed counterparts in an effort to assess model performance and, ultimately, to establish QPF bias corrections.

EVALUATION AND COMPARISON OF MICROPHYSICAL ALGORITHMS IN WRF-ARW MODEL SIMULATIONS OF ATMOSPHERIC RIVER EVENTS AFFECTING THE CALIFORNIA COAST

Isidora Jankov[1], Jian-Wen Bao[2], Paul J. Neiman[2], Paul J. Schultz[2], Huiling Yuan[3] and Allen B. White[2]

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Abstract

Numerical prediction of precipitation associated with five cool-season atmospheric river events in northern California was analyzed and compared to observations. The model simulations used the WRF-ARW model with four different microphysical parameterizations. This was done in conjunction with of the 2005-2006 field phase of the Hydrometeorological Testbed project, for which special profilers, soundings, and surface observations were implemented. Using these unique datasets, the meteorology of atmospheric river events was described in terms of dynamical processes and the microphysical structure of the cloud systems that produced most of the surface precipitation. Events were categorized as “bright band” (BB) or “nonbright band” (NBB), the difference being the presence of significant amounts of ice aloft (or lack thereof) and a signature of higher reflectivity collocated with the melting layer produced by frozen precipitating particles descending through the 0°C isotherm.

The model was mostly successful at predicting the timing of surface fronts, the development and evolution of low-level jets associated with latent heating processes and terrain interaction, and wind flow signatures were consistent with deep-layer thermal advection. However, the model showed the tendency to overestimate duration and the intensity of the impinging low-level winds. In general, all model configurations overestimated precipitation, especially in the case of BB events. Nonetheless, model runs using various microphysics parameterization schemes resulted in large differences in precipitation distribution and cloud structure.

CSTAR ACTIVITIES AT THE UNIVERSITY OF UTAH: ESTIMATING OPTIMAL DISTRIBUTIONS OF SURFACE OBSERVING STATIONS FOR EXISTING NETWORKS & TESTBEDS

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Abstract

The CSTAR-supported activities at the University of Utah are intended to improve the capabilities of operational forecasters to understand, analyze, and forecast high impact weather events that are strongly modulated by the characteristics of the underlying surface. The specific goals are: (1) utilize effectively mesonet observations for a variety of applications, (2) contribute to improvements in the NCEP Real Time Mesoscale Analysis and future Analysis of Record surface analyses and (3) enhance understanding, analysis, and prediction of high impact weather influenced by the underlying terrain through data analysis, real-data model simulations, improved conceptual models and training materials.

One research project, which is also supported with funding from the USFS, is to assess the impact on surface analyses of observations from the NWS/FAA and RAWS networks. Which stations provide redundant information relative to neighboring ones and which are most critical? A two-dimensional variational analysis system is used over CONUS subdomains to examine the sensitivity of mesoscale surface analyses to the observations assimilated. Analysis errors are assessed using data denial experiments in which each station is removed sequentially and all other stations retained for large samples of cases. Potential applications for these types of OSE studies for the design of testbeds and operational networks are discussed.

HIGH-RESOLUTION GLOBAL PRECIPITATION ANALYSES BASED ON MULTIPLE SATELLITE OBSERVATIONS AND IN SITU MEASUREMENTS

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Abstract

A suite of global precipitation analyses are being constructed at NOAA Climate Prediction Center (CPC) for improved quantitative applications in weather, climate, and hydrology. At the core of this CPC Unified Precipitation Suite is the CMORPH high-resolution (8kmx8km, 30min) global precipitation estimates defined by combining satellite observations from the TRMM and other satellites. Previous assessments and intercomparisons have shown that CMORPH presents excellent performance in documenting the spatial variation and temporal changes of precipitation but with regionally dependent and seasonally varying biases. With support from USWRP Hydrometeorological Testbed (HMT) Project, we are developing new techniques to further improve the CMORPH through a) applying a Kalman Filter-based objective analysis technique to more efficiently combine the information from multiple satellite estimates, and b) merging with gauge observations to remove the bias in the satellite observations.

In the Kalman Filter-based CMORPH approach, advection vectors of precipitating cloud systems are first computed from the consecutive cloud images from geostationary satellites. Maps of instantaneous precipitation rates derived from microwave observations from low earth orbit satellites (including TRMM, SSM/I et al) are then propagated in time and space along the advection vectors to get the first guess fields. This first guess is finally corrected with the IR-based precipitation estimates under the Kalman Filter framework to get the final precipitation analysis.

At the meantime, a new algorithm is developed to remove the bias in the CMORPH satellite precipitation estimates through matching the probability density function (PDF) of the satellite estimates with that of the concurrent gauge observations from the CPC Unified Global daily Gauge Analysis. Detailed results will be reported at the workshop.

DEVELOPING A PERFORMANCE MEASURE FOR SNOW-LEVEL FORECASTS

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Abstract

The snow level, or altitude in the atmosphere where snow changes into rain, is an important variable for hydrometeorological prediction in mountainous watersheds, yet, there is no operational performance measured associated with snow-level forecasts in the U.S. In order to establish a performance measure, it is necessary to first establish the baseline performance associated with snow-level forecasts. This presentation evaluates the skill of snow level forecasts produced by the California-Nevada River Forecast Center by comparing gridded point freezing level forecasts with observed freezing levels estimated by vertically pointing Doppler radars operating at 2875 MHz (S-band).

The evaluation occurred at two sites, one in the coastal mountains north of San Francisco, and one in the foothills of the Sierra Mountains in the American River Watershed. The evaluation was conducted for forecasts made during the winter wet season of 2005-2006. Although the overall mean freezing level forecast bias was small enough to not be hydrologically significant, about 15% of the forecasts had biases greater than 1,000 ft. The larges forecast biases were associated with freezing levels above 7,500 ft that were under-forecasted by as much as 3,000 ft. These high freezing level events were accompanied by the heaviest precipitation intensities, exacerbating the flood threat and making the forecast even more challenging.

STATUS AND PLANS FOR THE HYDROMETEOROLOGICAL TESTBED AT THE HYDROMETEOROLOGICAL PREDICTION CENTER

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Abstract

The Hydrometeorological Prediction Center (HPC) at NCEP is in the process of enhancing it's Hydrometeorological Testbed (HMT). The HPC HMT began with one part time meteorologist in August 2005. Currently, the HMT is staffed with a full time meteorologist with the participation of other HPC staff. The goal of the test bed is to enhance the transfer of research and the latest science into operations with a focus on improving HPC precipitation forecasts. The HPC HMT has worked with the NOAA HMT West in the application of techniques such as the use of standardized anomalies of moisture flux to identify atmospheric rivers. These techniques have been incorporated into the day to day forecast operations at HPC to provide up to 5 days of lead time for heavy rainfall events to forecasters and hydrologists along the West Coast. Future plans include the development of forecast techniques over other areas of the CONUS and initiating a visiting science program.

A REVIEW OF RECENT UALBANY CSTAR RESEARCH ON WARM-SEASON PRECIPITATION SYSTEMS INCLUDING PREDECESSOR RAIN EVENTS AHEAD OF TROPICAL CYCLONES

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Abstract

This presentation consists of two parts: a brief review of recent UAlbany CSTAR research on warm-season precipitation systems and a case study of a high-impact predecessor rain event (PRE) that occurred over the northern Great Plains and southern Great Lakes region in advance of Tropical Storm (TS) Erin on 19 August 2007.

PREs are coherent mesoscale regions of heavy rainfall (>100 mm in 24 h) that can occur ~1000 km poleward and eastward of recurving tropical cyclones (TCs). PREs typically occur ~24–36 h prior to the arrival of the main rainshield associated with the TC. A distinguishing feature of a PRE is that it is sustained by deep tropical moisture directly associated with the TC that is transported well poleward ahead of the TC. PREs are high-impact weather events that frequently result in significant inland flooding, either from the PRE itself or from the subsequent arrival of heavy rain associated with the TC that falls onto soils already saturated by the PRE rainfall.

In the case of TS Erin, widespread rainfall, with local amounts exceeding 250 mm, occurred in conjunction with a southerly stream of deep tropical moisture (precipitable water values >50 mm) directly from TS Erin that intersected a northwest-to-southeast oriented quasi-stationary baroclinic zone beneath the equatorward entrance region of an upper-level jet streak. Observations and numerical simulations using the Weather Research and Forecasting (WRF–ARW) model indicate that low-level frontogenesis was maximized during the overnight hours of 19 August 2007 and provided the forcing for vigorous ascent during the mature stage of the PRE. A preliminary finding of interest from a simulation using the WRF–ARW model in which the Erin moisture was removed ("dry run") shows a 30–40% decrease in total precipitation over the PRE region in the "dry run" compared to the control simulation. The extent of this decrease in total precipitation in the "dry run" underscores the importance of moisture originating from TS Erin in transforming an ordinary downstream heavy rain event into a high-impact, flood-producing rain event.

SHORT-RANGE COOL-SEASON PRECIPITATION FORECASTS DURING THE HYDROMETEOROLOGICAL TESTBED (HMT)-WEST PROGRAM

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Abstract

The Hydrometeorological Testbed (HMT)-West campaign has been implemented for three cool seasons in Northern California, covering the American River Basin (ARB). The ensemble system during the HMT-West project used high-resolution (3 km) time-lagged (initialized every 6 h) multimodel ensembles, including the Weather Research and Forecasting (WRF) model with two dynamic cores and multiple microphysical schemes. All models were driven by the diabatic initialization from the Local Analysis and Prediction System (LAPS) and the boundary conditions from the North American Mesoscale (NAM) forecasts. This study focuses on analyzing short-range (6-h and 24-h) quantitative precipitation forecasts (QPFs) and probabilistic QPFs (PQPFs) during the 2005/06, 2006/07, and 2007/08 winters for archived intensive operation periods (IOPs). Also, the cases during the 2008/09 winter with new model configurations for the Department of Water Resources in California are present. The verification was performed with data from the 4-km NCEP Stage IV precipitation analyses and available gauge data. Forecast errors were assessed for basin-scale, point-wise, and high-resolution QPFs. Ensemble-mean forecasts with different combinations were compared to the forecasts from individual models, and the impacts of ensemble configurations on forecast skill were examined in terms of microphysical scheme, dynamic core, and forecast lead time. The forecast quality of PQPFs was investigated at different precipitation thresholds and ensemble forecasts showed improved skill relative to the QPFs from individual models. Calibration plays an important role in bias correction of PQPFs. Skillful QPFs and PQPFs for the three cool seasons suggest advantages in using ensemble precipitation forecasts as the critical components in hydrological forecasting over the study domain.

GPS-MET DURING HMT-WEST 2009 WITH RECOMMENDATIONS FOR FUTURE TESTBEDS

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Abstract

As part of our contribution to HMT-West in 2009, ESRL/GSD evaluated the ability of operational numerical weather prediction models, specifically the NAM and GFS driven by the Local Analysis and Prediction System (LAPS), to extend useful predictions of IPW and the upslope component of the moisture flux out to at least 12h. Our study indicates that the GFS (which does not currently assimilate GPS observations) systematically underestimates IPW in the warm season compared with the NAM which does. Current state-of-the-art numerical weather prediction models allow us to predict IPW and the upslope component of the moisture flux with fairly good accuracy (15-25% error) out to 3h, but forecast skill rapidly diminishes after that. Model prediction approaches the skill of the model background without GPS in about 6h, and is virtually indistinguishable from the model background in 12h. We believe that the most likely causes of this and how quickly these errors propagate can be traced to errors in specifying the initial conditions at the boundaries of the models, and the inherent nonlinear variability of moisture in time and space. We also believe that these problems will impact almost all test bed activities that require the accurate specification of model state variables as a precondition for accurate short and long-term predictions.

On the basis of these results, we can make two recommendations for future directions in test beds that utilize GPS IPW and other moisture observations.

1. Short-term (0-3h) improvements in IPW and moisture flux displays. To accomplish this, we recommend the following activities in all testbed regions:
   a. Develop climatological thresholds for IPW and the upslope component of the moisture flux over CONUS and surrounding regions to provide forecasters with ***regionally targeted levels*** of warning for heavy precipitation events.
   b. Develop indices that inform operational forecasters when ***critical thresholds*** are approached or exceeded.
   c. Use "Smart Tools" already developed for the NWS Graphical Forecast Editor (LeFebvre et al. 2003) to read high-resolution 0-3h LAPS forecast grids and produce IPW, ***IPW Change and moisture flux map products*** that can be displayed on operational weather forecast workstations such as AWIPS and ALPS.

2. Longer-term (3h and beyond) improvements in QPF skill depend on more accurate specifications of the model boundary conditions. For all mass and momentum parameters, improved specifications of moisture and temperature are expected to make immediate improvements in forecast skill as discussed in Andersson et al. (2007). We ***strongly*** **recommend the following activities in support of all future testbed activities.**

a. Establish a joint program with NESDIS, NWS, and NOS to make continuous GPS observations on offshore platforms.

b. Take advantage of the agreements between NOAA and Shell Oil Company to install, operate and maintain GPS-Met observing systems on offshore platforms more than 40km offshore in the Gulf of Mexico.

c. Examine the utility of the methodologies described in Birkenheuer and Gutman (2005) and McMillin et al. (2007) to monitor and quantify microwave sounder observation errors over the open ocean.

d. Work with NCEP and JCSDA to apply these corrections to observations made from existing and future polar orbiting environmental satellites.

References

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OPTIMIZING PRECIPITATION ESTIMATES USING MERGED OBSERVATIONS AND MODEL OUTPUT: A CASE STUDY IN THE CALIFORNIA SIERRA NEVADA MOUNTAINS

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Abstract

Accurate and timely quantitative precipitation estimates (QPE) are critical for water management in regions such as the American River Basin in California where severe rainfall events can endanger levees and reservoirs. A method has been developed based on optimal data assimilation techniques used today in weather analysis to blend together high-resolution precipitation forecasts with point observations at rain gages or other estimates (for instance, radar). This method is applied to several winter storms during 2005-2007 in the American River Basin (ARB) northeast of Sacramento, California. For these storms, several high-resolution (3km horizontal grid spacing) Weather Research and Forecasting (WRF) model runs were performed with different microphysical packages, and from these runs lagged ensemble precipitation forecasts were produced. Carefully screened rain gage observations over a small domain over the ARB were then merged with the mean ensemble forecasts to produce precipitation estimates optimized as described above. To assess these 'optimum' fields, and compare to other forecasts and estimates, verification scores were derived using sets of gages withheld from each of several runs of the optimization procedure.

For an extreme rainfall episode between 29 December 2005 and 1 January 2006, the optimal QPE analyses qualitatively resembled the WRF ensemble forecasts, and were less smooth than other gage-only analyses. For example, on the Fig. 1, QPE (the blended forecast and gage observations described here), and the ensemble mean (which is a simple result of average of the individual ensemble members) reveal more detail related to terrain and model physics than the observation-based Stage IV analysis (a gridded RFC-based product based on gages complemented by climatological values). Verification scores for this event (Fig. 2) revealed that the optimal QPE were in many respects superior to another analysis (STMAS) based solely on gage data.

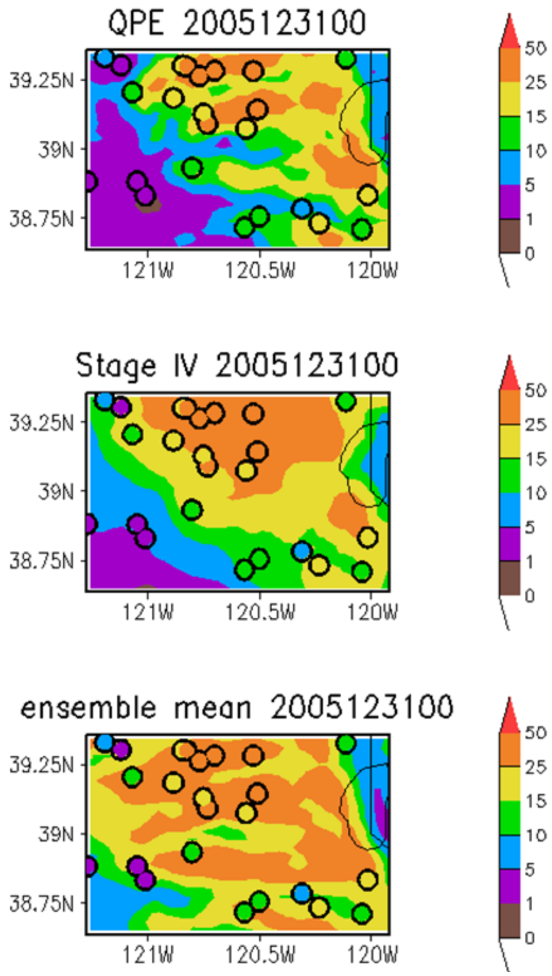

FIG. 1. Optimum precipitation analysis (QPE; top), Stage IV (middle), and WRF ensemble mean 6h forecast (bottom) valid at 0600 UTC December 31 2005 in the ARB domain. Color-coded circles are gages included in the QPE analysis. Legends are in units of mm.

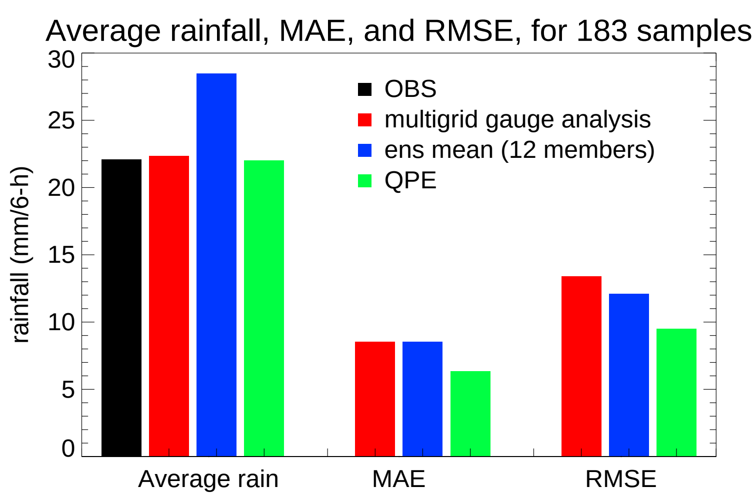

FIG. 2. ARB domain-average 6h rainfall (left bar cluster), mean absolute error (middle) and root-mean-square error (right) for all verification pairs during IOP 4. The black bar indicates straight average including all gages in the domain; other colors are as indicated in the legend.

RAINDROP SIZE DISTRIBUTION VARIABILITY ESTIMATED USING ENSEMBLE STATISTICS

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Abstract

Before radar estimates of the raindrop size distribution (DSD) can be assimilated into numerical weather prediction models, the DSD estimate must also include an uncertainty estimate. Ensemble statistics are based on using the same observations as inputs into several different models with the spread in the outputs providing an uncertainty estimate. In this study, Doppler velocity spectra from collocated vertically pointing profiling radars operating at 50 and 920 MHz were the input data for 42 different DSD retrieval models. The DSD retrieval models were perturbations of seven different DSD models (including exponential and gamma functions), two different inverse modeling methodologies (convolution or deconvolution), and three different cost functions (two spectral and one moment cost functions).

1. INTRODUCTION

The assimilation of radar precipitation estimates into numerical weather prediction models is a very difficult task because the numerical models require not only the precipitation estimate but also the uncertainty of that estimate. This implies that the radar precipitation estimate and its uncertainty must be computed and supplied to the numerical model before the model can assimilate the precipitation estimate.

There are four different types of uncertainties related to radar precipitation estimates: measurement error, model error, representativeness error, and sampling error [1]. Measurement Errors are due to the precision of the instrument. Model errors result from how well the observations are modeled using mathematical expressions (for example, how well the raindrop size distribution is described using exponential or gamma functions). Representativeness errors are due to the time evolving changes and the spatial inhomogeneity of the precipitation within in the sample volume during the observation dwell time. And sampling errors result from the changes in precipitation in the same sample volume between successive observations.

This study focuses on quantifying the model errors of precipitation estimates retrieved from vertically pointing profiling radars. The same Doppler velocity spectra are used as input into 42 different raindrop size distribution (DSD) retrieval models to produce 42 estimates of rainrate and mean mass-weighted raindrop diameter D_m. The ensemble statistics of these 42 different models provides a model uncertainty needed for assimilating the precipitation estimates in numerical weather prediction models.

2. OBSERVATIONS

Observations from two collocated profilers near Darwin, Australia, are used in this study. One profiler operated at 50 MHz (VHF) and the other at 920 MHz (UHF). Several studies have used these two profilers to retrieve the vertical structure of raindrop size distributions [2, 3].

Figure 1 shows the reflectivity-weighted Doppler velocity spectra as a function of range for the two vertically pointing radars on 3 January 2002 at 0500 UTC. The VHF radar spectra are on the right of Figure 1 with the signals from the air motion and precipitation indicated in the panel. The asterisks indicate the estimated air motion from the 50-MHz profiler and are repeated in the left panel that shows the 920-MHz radar spectra. This example is during stratiform rain as indicated by the 920-MHz profiler radar brightband in reflectivity near 4.4 km. Another indicator of stratiform rain is the transition in fall speed as snow and ice particles above 5 km melt and fall faster as raindrops below 4 km.

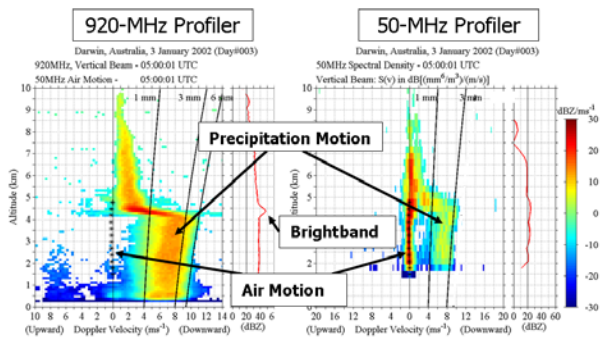

FIG 1. Reflectivity-weighted Doppler velocity spectra as a function of range for the 920-MHz profiler (left) and 50-MHz profiler (right) for 3 January 2002 at 0500 UTC. The air motion and precipitation motion observed in the 50-MHz profiler spectra are identified. Only the precipitation motion is observable in the 920-MHz profiler spectra with the asterisks indicating the 50-MHz profiler estimated air motion.

3. DSD MODEL DESCRIPTION

Assuming a perfect radar with infinitesimal beamwidth and a static atmosphere with zero vertical air motion and zero turbulence, the observed reflectivity-weighted Doppler spectral density, $S_{hydrometeor}(v)$, is uniquely related to the raindrop size distribution, $N(D)$, through the relation [4]:

$$S_{hydrometeor}(v) = N(D)D^6 dD/dv \qquad (1)$$

where v and dv are the velocity and velocity resolution of the Doppler spectrum in units of m s^{-1} and D and dD are the diameter and diameter resolution corresponding to each v and dv in units of mm. Of course, D has positive definite values and D and dD are valid only when v corresponds to downward air-density corrected raindrop terminal fall speeds. Through laboratory studies, the transformation from velocity to diameter space in equation (1) is facilitated with a raindrop diameter to terminal fall speed relationship expressed as:

$$V_{fall\ speed}(D) = \left(9.65 - 10.3\exp(-0.6D)\right)\left(\frac{\rho}{\rho_0}\right)^{-0.4} \qquad (2)$$

where ρ_0 and ρ represent the air densities at the ground and the level of the observation aloft, respectively [4]. The Doppler velocity reflectivity spectral density observed by a radar is not just the simple expression of equation (1), but is the reflectivity spectral density shifted by the ambient air motion and broadened by the turbulent motions and horizontal wind motions within the radar pulse volume. For the 920-MHz profiling radar, the observed reflectivity spectral density, $S_{observed}(v)$, can be expressed as:

$$S_{observed}(v) = S_{air}(v - \omega, \sigma_{air}) * S_{hydrometeor}(v) \qquad (3)$$

where $S_{air}(v\text{-}\omega,\sigma_{air})$ is the spectral-shift and spectral-broadening function corresponding to the vertical air motion, ω, and total spectral broadening, σ_{air}, and the symbol * refers to the convolution function [5].

4. SOLVING THE DSD MODEL

While equation (3) describes the observed radar reflectivity Doppler velocity spectrum, $S_{observed}(v)$, as the convolution of two functions, we really want to know the raindrop size distribution *N(D)* contained in $S_{hydrometeor}(v)$. There are two methods of solving for $S_{hydrometeor}(v)$: the Convolution Technique, and the Deconvolution Technique. The convolution technique is actually a fitting technique that searches for the best solution and with each guess equation (3) is evaluated using the forward convolution calculation. The deconvolution technique determines $S_{hydrometeor}(v)$ by performing a deconvolution directly on equation (3). The benefits and limitations of both techniques are described below.

4.1. Convolution Technique (Fitting Technique)

The Convolution Technique searches for the best solution by iterating through different raindrop size distributions *N(D)* until a cost function is minimized. This technique to solve equation (3) has been used in many studies including [2, 3, 5-7]. For each possible solution, a test $S_{hydrometeor}(v)$ spectrum is constructed, then convoluted with the shifting and spectral broadening function $S_{air}(v\text{-}\omega,\sigma_{air})$ and the model function $S_{model}(v)$ is compared with the observed spectrum $S_{observed}(v)$. Figure 2 shows a flow diagram of the Convolution Technique. The top portion of Figure 2 shows the inputs into the model, and the bottom portion of Figure 2 shows the calculations performed in the model.

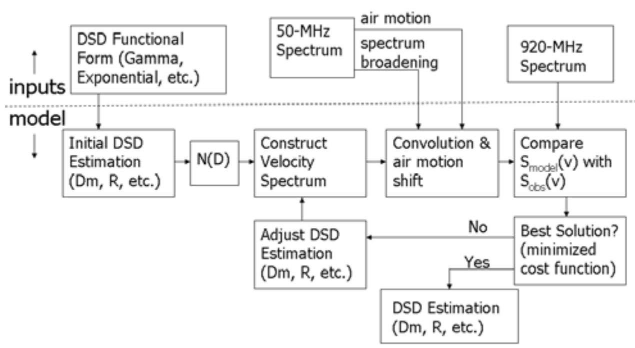

FIG 2. Convolution Technique flow diagram. The inputs to the model are above the dashed line and the model flow diagram is below the dashed line. The loop in the lower right corner is repeated until the solution minimizes a cost function.

One limitation of the Convolution Technique is that the mathematical form of the DSD must be specified as an input to the model. The five functional forms of the DSD used in this study included the exponential, the gamma, the normalized gamma, the Log-Normal, and the gamma function with constant μ=2.

4.2. Deconvolution Technique

The Deconvolution Technique performs a deconvolution on equation (3) to produce an estimate of $S_{hydrometeor}(v)$ [3, 6]. Figure 3 shows the Deconvolution Technique flow diagram. One limitation of the Deconvolution Technique is that the deconvolution routine may become unstable and amplify the noise in the observed spectrum producing an unrealistic solution. After the original spectrum has been deconvolved, one of the functional forms is used to estimate the DSD.

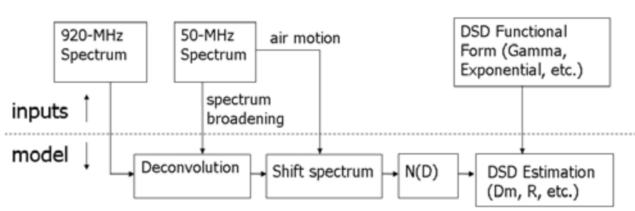

FIG 3. Deconvolution Technique flow diagram. The inputs to the model are above the dashed line and the model flow diagram is below the dashed line.

5. ENSEMBLE STATISTICS

This study used seven different functional forms of the DSD, the Convolution and Deconvolution fitting techniques, and three cost functions (not shown due to space limitations). Therefore, for each observed radar spectrum, 42 DSD estimates were produced. The mass-weighted mean diameter, D_m, and the rainrate, *R*, were calculated for each of the 42 retrievals. The mean and standard deviation of these 42 solutions (both for D_m and *R*) produced the ensemble mean and the ensemble uncertainty.

In order to see the spread in the 10 different retrievals, Figure 5 shows the spread of the D_m estimates relative to the ensemble mean value. The spread is expressed using the expression $\Delta D_m = D_m^k - \overline{D_m}$, where D_m^k is the k^{th} retrieval (from 1 to 10) and $\overline{D_m}$ is the ensemble mean. Panel (*a*) shows the probability distribution function (PDF) of ΔD_m, panel (*b*) shows the spread of the ΔD_m for small ranges of $\overline{D_m}$, and panel (*c*) shows the PDF of $\overline{D_m}$.

Figure 4 shows a precipitation event from 16 February 2003 with the time-height cross-section of 920-MHz profiler reflectivity shown in panel (a) and the reflectivity at 3.2 km range in panel (b). The ensemble mean D_m and *R* for the 3.2 km range are shown in panels (c) and (d) in black with +/- one ensemble standard deviation (STD) shown in blue.

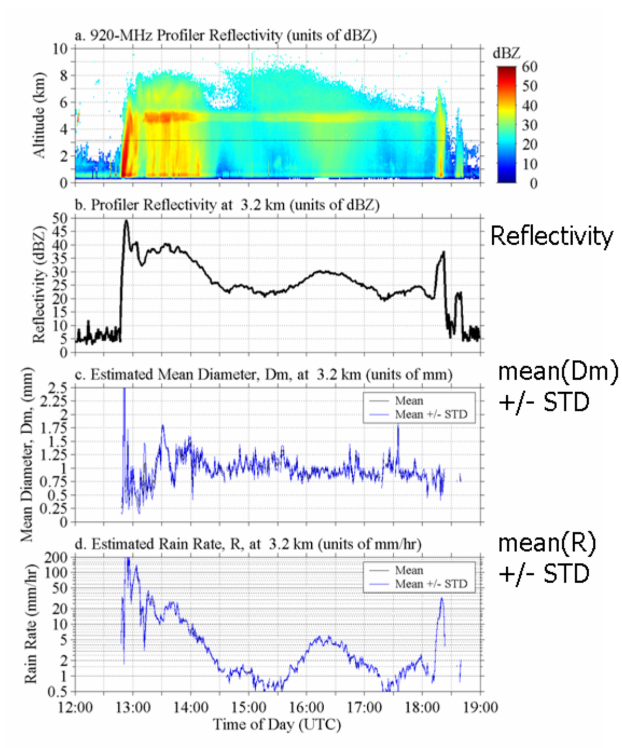

FIG 4. Example of ensemble mean and uncertainties retrieved from 16 February 2003 observations. (*a*) Time-height cross-section of 920-MHz profiler reflectivity, (*b*) reflectivity at a height of 3.2 km, (*c*) ensemble mean mass-weighted mean diameter D_m (black line)

and plus/minus ensemble D_m standard deviation (blue lines), and (d) ensemble mean rainrate R (black line) and plus/minus ensemble R standard deviation (blue lines).

The spread of the retrieved rainrate for the 10 DSD models is expressed as a percent difference using $\%R = 100\left(\frac{R_k - \overline{R}}{\overline{R}}\right)$ where R_k is the k^{th} retrieval (from 1 to 10) and $\overline{R}$ is the ensemble mean rainrate. The ensemble statistics for the rainrate is shown in Figure 6.

6. CONCLUDING REMARKS

As radar precipitation estimates are provided to real-time weather forecast and to cloud resolving models, the uncertainties of those estimates must also be provided. Ensemble modeling provides a way of estimating the radar precipitation retrieval uncertainties.

This study used observations from 16 February 2003 near Darwin, Australia, to evaluate the ensemble statistics of D_m and rainrate retrieved from a pair of 50- and 920-MHz profilers. Analysis from this single rain event suggests that the variation in D_m relative to the ensemble mean has a standard deviation of about 0.1 mm, and the variation in rainrate has a standard deviation of about 11%. The ensemble statistics address the relative error of different retrieval methods and does not address the absolute error or bias of the precipitation estimates as would be caused by a miscalibration of the radar.

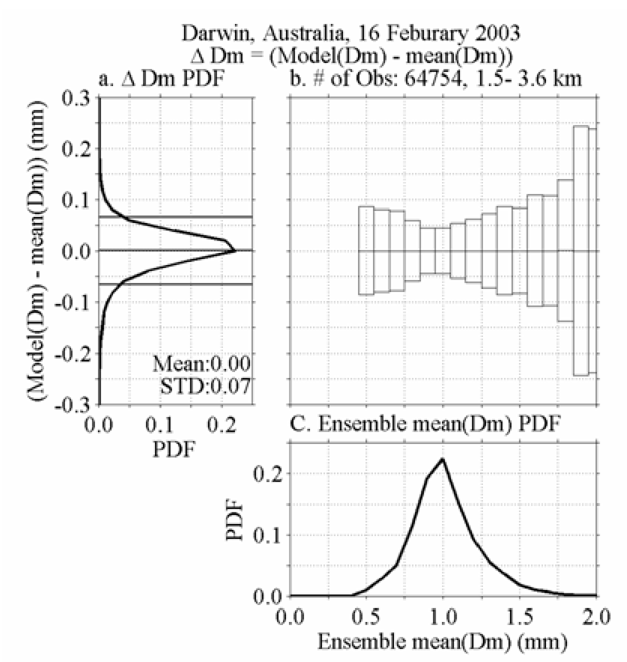

FIG 5. Statistics relative to the ensemble mean Dm. (a) Probability distribution function (PDF) of ΔD_m, (b) shows the spread of the ΔD_m for small ranges of $\overline{D_m}$, and (c) shows the PDF of $\overline{D_m}$.

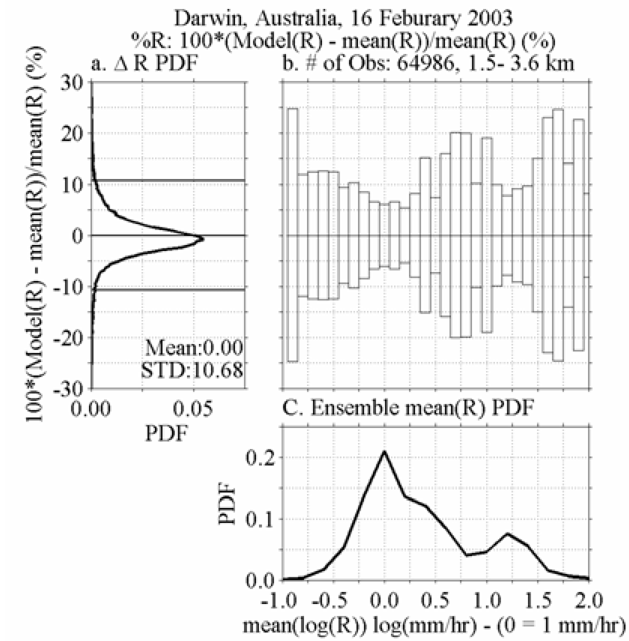

FIG 6. Statistics relative to the ensemble mean rainrate *R* expressed as a percentage of the mean rainrate. (*a*) Probability distribution function (PDF) of $\Delta\%R$, (*b*) shows the spread of the $\Delta\%R$ for small ranges of $\overline{R}$, and (*c*) shows the PDF of $\overline{R}$. Note that log(R) has units of dB.

7. ACKNOWLEDGMENTS

This work was supported in part by NASA Precipitation Measuring Mission (PMM), and in part by NOAA's contribution towards the NASA PMM program.

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VERIFICATION AT THE DTC

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Abstract

Verification at the DTC has evolved considerably over several years, from the initial adoption of the NCEP Verification Systems through the development and enhancement of MET verification suite. New capabilities continue to be added as needs are identified. This presentation contains a brief overview of DTC verification capabilities and real-time MET use for the HWT Spring Experiment is presented. Plans for collaboration with HWT are discussed and potential benefits to other testbeds are highlighted.

HURRICANE WRF AT THE DTC

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Abstract

Hurricane WRF (HWRF) is a specialized version of the WRF-NMM that is designed to forecast tropical storms. HWRF is developed at EMC based upon WRF-NMM dynamic core Version 2. DTC is working on updating HWRF to WRF-NMM dynamic core Version 3, and then porting HWRF into WRF repository.

HWRF has some unique features that make it suitable in forecasting hurricanes. The following features will be discussed.

1) Movable, two-way nested grid. The grid size is 27 km for the outer grid, and 9 km for the inner.
2) Advanced physics, including atmosphere/ocean fluxes, GFS boundary Layer and SAS convection.
3) Vortex initialization techniques, including GSI 3Dvar and vortex bogusing/relocation.
4) Ocean coupling. Currently Princeton ocean model (POM) is the ocean component.

The work being done at the DTC lays down a foundation for a new relationship between the research and operational communities. In the future, it is likely that upgrades to HWRF proposed by JHT researchers will be first committed to the WRF repository and later extensively tested for a potential operational implementation.

THE HFIP HIGH RESOLUTION HURRICANE TEST

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Abstract

Tropical cyclones are a serious concern for the nation, causing significant risk to life, property and economic vitality. The NOAA National Weather Service has a mission of issuing tropical cyclone forecasts and warnings, aimed at protecting life and property and enhancing the national economy. In the last 10 years, the errors in hurricane track forecasts have been reduced by about 50% through improved model guidance, enhanced observations, and forecaster expertise. However, little progress has been made during this period toward reducing forecasted intensity errors.

To address this shortcoming, NOAA established the Hurricane Forecast Improvement Project (HFIP) in 2007. HFIP is a 10-year plan to improve one to five day tropical cyclone forecasts, with a focus on rapid intensity change. Recent research suggests that prediction models with grid spacing less than 1 km in the inner core of the hurricane may provide a substantial improvement in intensity forecasts. The 2008-09 staging of the high resolution test aims at quantifying the impact of increased horizontal resolution in numerical models on hurricane intensity forecasts. The primary goal of this test is an evaluation of the effect of increasing horizontal resolution within a given model across a variety of storms with different intensity, location and structure. A secondary goal is to provide a data set that can be used to explore the potential value of a multi-model ensemble for improving hurricane forecasts.

The Developmental Testbed Center (DTC) and the HFIP Team hosted a workshop at the National Hurricane Center in Miami, FL, 11-12 March 2008. Experts on hurricanes, numerical modeling and model evaluation met for two days to discuss the strategy for this test. The test plan that was put together following this workshop reflects the consensus reached on the framework for this testing effort. Six modeling groups are participating in the testing effort. This presentation will briefly describe the basic elements of the test and summarize the results of the objective evaluation performed by the DTC for the available model data.

JOINT EFFORTS BETWEEN THE DTC AND THE HMT

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Abstract

The Weather Research and Forecasting (WRF) Developmental Testbed Center (DTC) and the Hydrometeorlogical Testbed (HMT) Program share many common interests, such as testing and evaluation of high-resolution numerical weather prediction (NWP) models and the transfer of research results into operations. Thus, it is natural that a collaborative effort would be developed between the two organizations. This collaboration – which was recently initiated – will focus on four primary areas: (1) implementation and demonstration of verification capabilities for high-resolution NWP forecasts, (2) development of capabilities in the DTC for high-resolution ensemble prediction, (3) data impact studies, and (4) evaluations of impacts of model physics and parameterizations. Initial effort will be focused on areas (1) and (2). For Area (1), existing DTC capabilities will be implemented [e.g., based on the DTC's Model Evaluation Tools (MET)] for evaluation of forecasts in the HMT West region and a demonstration of these capabilities will be provided for the winter 2009-2010 forecasts. Area (2) represents a new focus for the DTC; the most effective way for the DTC to provide community support for ensemble prediction, including predictions that are relevant for the HMT, will be identified through workshops and other joint activities between the HMT, DTC, and other community members. Working groups will be established to develop plans for collaboration in Areas (3) and (4). As the HMT efforts move to other regions (e.g., the Southeast U.S.), the focus of DTC/HMT collaborations will also transition to these regions, and the joint activities will evolve to meet new challenges.

NOAA Testbed USWRP Workshop

28-29 April 2009

NOAA Earth System Research Laboratory, Boulder, Colorado

Wednesday, April 29th

8:00 Coffee & light breakfast

8:30 **Connections to other NOAA Programs, Projects & Activities that Involve R2O**

Research to Operations in the Joint Center for Satellite Data Assimilation – *Steve Goodman (NOAA)*

THORPEX – *John Gaynor (NOAA)*

SPoRT – An End-to-End R2O Activity – *Gary Jedlovec (NASA)*

The Hazardous Weather Testbed – *Jack Kain (NSSL)*

The GOES-R Proving Ground – *Steve Goodman (NOAA)*

10:15 Break

10:30 **Testbed Roundup 3 – Joint Hurricane Testbed**

11:45 Lunch (on-site)

12:45 **Testbed Roundup 4 – Societal Impacts Program**

1:15 **Group Discussion** – moderator, *John Gaynor*

2:00 Break & light snack

2:15 **Testbed Breakout Sessions**

3:30 **Team Report-outs, Group Discussion** & **Workshop Wrap-up** – *Marty Ralph*

4:45 **Adjourn Workshop**

5:00 Happy Hour (Walnut Brewery)

RESEARCH TO OPERATIONS IN THE JOINT CENTER FOR SATELLITE DATA ASSIMILATION

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Abstract

Although much of the recent progress in skill of the operational numerical weather prediction systems can be attributed to improvements in satellite remote sensing and in assimilation methodology, there is broad agreement in the community that more needs to be done to exploit the data from the new advanced sensors to realize their full potential. The Joint Center for Satellite Data Assimilation was formed in 2001 to address this issue and is tasked with accelerating and improving the use of the existing satellite data as well as preparing for new measurements from planned US and international operational and research satellites. This talk will provide an overview of the Joint Center and the efforts undertaken by the center and its partners within NASA, NOAA and the Department of Defense toward this goal. Special emphasis will be placed on the role of the Joint Center in transitioning new data into operational use and in maintaining their impact over the lifetime of the respective sensors.

THORPEX

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Abstract

THORPEX is a WMO program designed to accelerate improvements in global forecasts of high impact weather out to 14 days. There are over a dozen countries involved in THORPEX. THORPEX will reach its goals through research in:

- Predictability and dynamical processes
- Data assimilation and observing strategies research
- Societal and economic applications

In NOAA, the focus has been on the first two. Much work is being done on data assimilation, bias correction and various filtering schemes to improve ensemble global models. Just completed was a field campaign from Siberia to the US and Canadian Pacific Coast called the Winter Pacific Asian Regional Campaign (Winter T-PARC) involving enhanced radiosondes and airborne dropsondes. The goal was to improve and extend high impact weather predictions along the US and Canadian west coasts and in the eastern US.

This experiment and the work on ensemble-based probabilistic prediction form the bases (boundary and initial conditions) for links to regional and mesoscale ensemble prediction and hence a link to the model-based test beds. These potential links will be described.

SPoRT – AN END-TO-END R2O ACTIVITY

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Abstract

Established in 2002 to demonstrate the weather and forecasting application of real-time EOS measurements, the Short-term Prediction Research and Transition (SPoRT) program has grown to be an end-to-end research to operations activity focused on the use of advanced NASA modeling and data assimilation approaches, nowcasting techniques, and unique high-resolution multispectral observational data applications from EOS satellites to improve short-term weather forecasts on a regional and local scale. SPoRT currently partners with several universities and other government agencies for access to real-time data and products, and works collaboratively with them and operational end users at 13 WFOs to develop and test the new products and capabilities in a "test-bed" mode. The test-bed simulates key aspects of the operational environment without putting constraints on the forecaster workload. Products and capabilities which show utility in the test-bed environment are then transitioned experimentally into the operational environment for further evaluation and assessment. SPoRT focuses on a suite of data and products from MODIS, AMSR-E, and AIRS on the NASA Terra and Aqua satellites, and total lightning measurements from ground-based networks. Some of the observations are assimilated into or used with various versions of the WRF model to provide supplemental forecast guidance to operational end users. SPoRT is enhancing partnerships with NOAA / NESDIS for new product development and data access to exploit the remote sensing capabilities of instruments on the NPOESS satellites to address short term weather forecasting problems. The VIIRS and CrIS instruments on the NPP and follow-on NPOESS satellites provide similar observing capabilities to the MODIS and AIRS instruments on Terra and Aqua. SPoRT will be transitioning existing and new capabilities into the AWIIPS II environment to continue the continuity of its activities.

NOWCASTING APPLICATIONS AT THE GOES-R SATELLITE PROVING GROUND

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Abstract

The key mission of the Satellite Proving Ground is to demonstrate new satellite observing data, products and capabilities in the operational environment to be ready on Day 1 to use the Geostationary Operational Environmental Satellite (GOES-R) suite of measurements. Algorithms, tools, and techniques must be tested, validated, and assessed by end users for their utility before they are finalized and incorporated into forecast operations. The GOES-R Proving Ground proxy data for the 16-channel Advanced Baseline Imager (ABI) and Geostationary Lightning Mapper (GLM) focus on evaluating how the infusion of the new technology, algorithms, decision aids, or tailored products integrate with other available tools in the hands of the forecaster responsible for issuing forecasts and warning products. Proxy fields and products for ABI are derived from simulated mesoscale model data and satellite sensors such as the Earth Observing System (EOS) Terra/Aqua MODIS and Meteosat SEVERI.

The GLM proxy data are derived from the EOS Lightning Imaging Sensor and available ground-based total lightning VHF mapping networks. Additionally, the testing concept fosters operation and development staff interactions which will improve training materials and support documentation development. Planned assessments of ABI and GLM proxy products - Convective Initiation, Statistical Severe Weather Forecast, Total Lightning Density and Trends - for severe storm warning and forecasting will be provided to NWS forecasters during the 2009 Hazardous Weather Testbed Spring Experimental Forecast and Warning Program during the period April 27-June 10 will be discussed.

EVALUATION AND IMPROVEMENT OF OCEAN MODEL PARAMETERIZATIONS FOR NCEP OPERATIONS

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Abstract

This project is supported by the Joint Hurricane Testbed and is designed to evaluate and improve the performance of coupled hurricane forecast models, particularly in regards to intensity evolution. The emphasis is on the capability of the ocean model to forecast SST evolution and the resulting thermodynamical feedback to the atmosphere that impacts storm intensity. To date, the project has focused on evaluation and improvement of the HYbrid Coordinate Ocean Model (HYCOM) in terms of forecasting the upper ocean and SST response to hurricanes. This ocean model is now being tested at NOAA/NCEP/EMC as the ocean component of the next-generation HWRF hurricane forecast model.

Key objectives of this project include (1) improve ocean model initialization; (2) determine the optimal choice of both horizontal and vertical resolution enabling HYCOM to run as efficiently in the TC forcing environment without degrading performance; (3) quantify sensitivity to horizontal and vertical mixing parameterizations and determine strategies to improve these parameterizations; (4) collaborate with groups working to improve surface flux parameterizations to be sure that the optimal aerodynamic drag coefficients are used in the model; and (5) maintain a strong two-way collaboration with the NOAA/NCEP/EMC team developing the coupled HWRF model. A critical aspect of this work is evaluation of the ocean model against high-quality upper ocean observations taken before, during, and after storm passage. Initial results of this project are presented, emphasizing the thorough evaluation of HYCOM in simulating the ocean response to hurricane Ivan (2004), the potential impact of ocean model performance on hurricane intensity forecasts, and the most productive strategies for improving ocean model performance.

URI CONTRIBUTION TOWARDS IMPROVING THE GFDL/GFDN AND HWRF OPERATIONAL HURRICANE MODELS UNDER JHT FUNDING AND FUTURE PLANS

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Abstract

Under JHT funding, our group at the University of Rhode Island (URI) has been actively involved in the improvement of the operational GFDL, GFDN, and HWRF coupled hurricane models for real-time hurricane forecasting. From 2003-2006, URI took the lead on the following improvements to the operational GFDL model: (1) a new ocean model configuration and data assimilation package with improved initialization of the Gulf Stream, Loop Current, and warm- and cold-core rings in the Gulf of Mexico, (2) ocean coupling in the East Pacific, (3) increased resolution in the atmospheric model, and (4) a new air-sea momentum flux parameterization with an improved estimation of the drag coefficient based on coupled wave-wind model simulations. Since 2006, URI has focused on (1) transitioning the improvements in the operational GFDL model to the operational GFDN model at FNMOC and the operational HWRF model at NCEP and (2) developing new improvements to the GFDN and HWRF models. Some of these new improvements under various stages of development include: (1) further increasing the resolution of the atmospheric and ocean models, (2) coupling with the WAVEWATCH III model, (3) implementing the new URI air-sea interface model coupled with the ESRL sea spray model, and (4) specifically in the GFDN model, implementing ocean coupling with the Navy's NCODA real-time ocean analysis in all ocean basins. JHT support is crucial for continued development and for transitioning new model improvements into operations.

IMPACT OF SEA SPRAY ON THE BALANCE OF TURBULENT KINETIC ENERGY IN THE HURRICANE SURFACE BOUNDARY LAYER

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Abstract

The feedback effects of sea-spray on the mean wind, temperature and moisture profiles in the surface boundary layer associated with tropical cyclones is investigated using a 1-D coupled sea-spray and surface boundary layer (SBL) model. This model is capable of simulating the microphysical aspects of evaporation of saline water droplets of various sizes and their dynamic and thermal interaction with the turbulence mixing that is simulated by the Mellor-Yamada 1.5-order closure scheme. The sea-spray droplet generation is described by a state-of-the-art parameterization which predicts the size spectrum of sea-spray droplets at a given surface stress (or wind speed). The results from a series of simulations reveal salient characteristics of the way in which evaporating droplets of various sizes modify the turbulence mixing near the surface, which in turn affects further droplet evaporation.

Based on these results, a bulk parameterization scheme of sea-spray mediated air-sea heat and momentum fluxes has been developed at NOAA/ESRL. Results from testing the scheme with the current operational setup of the HWRF model indicate that the scheme may be used as a way to reduce the weak intensity bias since the scheme's impact on hurricane track prediction is small enough that it can be neglected. It is found that because the very turbulence that transports momentum and heat across the air-sea interface is also responsible for the generation of sea spray, the resultant effect of sea spray on both the momentum and heat fluxes is complicated by the interaction between the sea spray, turbulence and mean flow.

PACIFIC OCEAN TROPICAL SYNOPTIC REGIMES AND THEIR EFFECT AND IMPORTANCE ON THE GLOBE

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Abstract

Numerous writings and even Tropical Meteorology textbooks have been erroneous in the naming convention of the synoptic fields within the Deep Tropics. What may be the Near-Equatorial Trough, the Monsoon Trough, or the Mei-yu front have often been mis-labeled as the Inter-Tropical Convergence Zone (ITCZ). This may be due in part to the sheer lack of data to properly identify the wind fields or structures of these synoptic patterns. We are in the process of producing a paper to better understand tropical structures, wind fields and synoptic patterns with the use of published research, Satellite Ocean Surface Vector Wind Observations and experts in the field. Some of the aforementioned regimes play a significant role in the transportation of energy throughout the globe; whereas features, such as the ITCZ, accounts for only a small portion of the energy global transportation.

THE U.S. PUBLIC'S PERCEPTIONS OF WEATHER FORECASTS AND FORECAST UNCERTAINTY: RESULTS FROM A SURVEY

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Abstract

This presentation will discuss recent Societal Impacts Program research to help improve communication of weather forecasts and forecast uncertainty by investigating how members of the public receive, perceive, interpret, and use weather forecasts. Results will be presented from a nationwide survey that examined the public's perspectives on everyday weather forecasts, including forecasts containing uncertainty information. The results presented examine communication of everyday weather forecasts to the general public, but aspects of the results may also be applicable to other types of hydrometeorological forecasts and to more specialized audiences. Topics investigated include people's sources and uses of weather forecasts, their uncertainty-related interpretations of deterministic forecasts, their confidence in different types of forecasts, and their interpretations of probability of precipitation forecasts. We also explore people's preferences for deterministic forecasts versus those that express uncertainty and their preferences for different uncertainty communication formats. Areas of ongoing and future related research will also be discussed.

SOCIO-ECONOMIC RESEARCH ON HURRICANE FORECASTS AND WARNINGS: A DISCUSSION OF RESULTS AND RESEARCH PLANS

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Abstract

We will discuss our research program on socio-economic aspects of the hurricane forecast and warning system. We will present methods and results from a small sample survey of Miami households on their uses, perceptions, and values for current and improved forecasts. This will include a discussion of non-market approaches for deriving values for hurricane forecasts. Our discussion will then provide a brief overview of three funded projects examining different yet related aspects of the hurricane forecast and warning process integrating a variety of social sciences. These projects are: (1) the NOAA funded *Hurricane Forecast Improvement Project Socio-Economic Impacts Assessment* project, focusing on assessment of emergency managers' needs, uses, and decision-making primarily with respect to hurricane intensity forecast information and households' values for improved intensity forecasts related to NOAA's Hurricane Forecast Improvement Project. (2) the 3-year NSF funded project *Warning Decisions in Extreme Weather Events* implementing a multidisciplinary, multi-method approach to better understand flash flood and hurricane warning systems, and (3) the 2-year NSF and NOAA funded *Communicating Hurricane Information* project researching the process through which advisories and warnings are developed and the resulting content, the communication channels used by various actors in this process, and how at-risk coastal residents, including more vulnerable populations, comprehend and react to specific components of advisories and warnings.

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